these situations. In one instance, in which the blood-vessels of the brain were found to be much congested, inoculation of a tube of sloping agar with a large platinum loopful of cerebro-spinal fluid, well spread over the surface of the agar, resulted in the appearance of half a dozen isolated colonies of a pure culture of the distemper bacillus.

By heating a broth culture of the bacillus at 60° C. for half an hour, and subsequently adding a small quantity of carbolic acid as a preservative, a vaccine is obtained, which acts in similar fashion to those devised by Haffkine and Wright for use in the prevention of plague and enteric fever respectively. The vaccine may be standardised after the manner originally suggested by Wright in connection with his work on enteric fever.

The dose must obviously vary according to the size of the dog, but, as a guide, it may be mentioned that I have found, in three instances, that the injection of 2 c.c. of the sterilised culture of the bacillus is apparently sufficient to protect fox-terrier puppies weighing about $1\frac{1}{2}$ kilos. against attack by distemper, while an unprotected puppy in the same batch contracted the disease on introduction of an affected dog. I find also that guinea-pigs can be protected in this way against the effects of a dose of living culture, which would ordinarily prove fatal in about forty-eight hours. As regards the exact length of time, however, during which such protective effect may last, no definite statement can as yet be made, but a series of tests on a large scale are in process of being carried out by dog-breeders in this country, in Germany, and in America.

"On the Tempering of Iron hardened by Overstrain."* By JAMES MUIR, B.Sc., B.A., Trinity College, Cambridge, 1851 Exhibition Research Scholar, Glasgow University. Communicated by Professor EWING, F.R.S. Received July 11,—Read December 6, 1900.

(Abstract.)

It is well known that iron hardened by overstrain, for example, by permanent stretching, may have its original properties restored again by annealing, that is, by heating it above a definite high temperature and allowing it to cool slowly. Experiments described in the paper, of which this is an abstract, show, however, that if iron hardened by overstrain be raised to any temperature above 300° C., it may be partially softened in a manner analogous to the ordinary tempering or

* The work described in this paper is a continuation of that already described in a paper by the present author "On the Recovery of Iron from Overstrain," 'Phil. Trans.,' A, vol. 193, 1899.

"letting down" of steel which has been hardened by quenching from a red heat. This tempering from a condition of hardness induced by overstrain, unlike ordinary tempering, is applicable not only to steel, but also to wrought iron, and possibly to other materials which can be hardened by overstrain and softened by annealing.

The experiments described in the paper were all carried out on rods of iron and steel about $\frac{5}{8}$ths of an inch in diameter and 11 inches long, the elastic condition of the material being in all cases determined by means of tension tests in which the hardness of the material was indicated by the position of the yield-point. The straining was performed by means of the 50-ton testing machine of the Cambridge Engineering Laboratory, and the small strains of extension were measured by an extensometer of Professor Ewing's design, which gave the extension on a 4-inch length of the specimen to the 1/100,000th of an inch.

For the purpose of tempering and annealing, a gas furnace was employed 2 feet in length, the specimens being protected from direct contact with the flame by inclosing them in a thick porcelain tube. The temperature inside this tube was determined by means of a Callendar's direct-reading platinum-resistance pyrometer.

The method of examining the materials employed is illustrated by the following two diagrams, in which the material examined is a $\frac{1}{2}$-inch rod of semi-mild steel (0·35 per cent. C., 1 per cent. Mn).* Curve No. 1 of the first diagram shows that this steel when in the condition as supplied by the makers gave a well-defined yield-point at about 38 tons per square inch, the material yielding at that stress by 0·13 of an inch on a 4-inch length.

Curve No. 2 illustrates the semi-plastic state of the material, produced by just passing this primary yield-point. The specimen was laid aside for $1\frac{3}{4}$ days, then once more tested; and Curve No. 3 shows the progress made during this interval of rest towards recovery of elasticity. Curve No. 4 shows the condition of the overstrained material after it had been resting for two weeks. To insure perfect recovery of elasticity, the specimen was heated to 200° C., but a few minutes at the temperature of boiling water would have been nearly as effective in restoring the elasticity lost by overstrain.†

After cooling, the specimen was tested by reloading and carefully increasing the load above its previous maximum amount till a well-defined yield-point was obtained at 49 tons per square inch, as shown by Curve No. 5, the yield-point having thus been raised by the large step of 11 tons per square inch. The yielding which occurred at this

* Details of the special method adopted in plotting these diagrams will be found in the author's previous paper "On the Recovery of Iron from Overstrain,' 'Phil. Trans.,' A, vol. 193, 1899, p. 12.

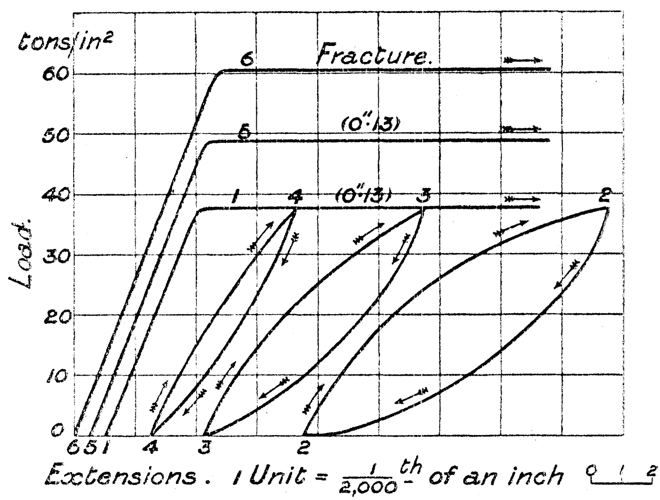
† *Ibid.*, p. 22.

yield-point was the same as obtained in the first test of the specimen, namely, 0·13 of an inch on 4 inches.

The material after this second overstrain was once more in a semi-plastic state. A curve obtained immediately after the overstrain would have been similar to Curve No. 2, but the loading could have been continued up to 49 tons per square inch. Had the loading been continued beyond this amount while the material was in the semi-plastic state, large yielding would have taken place, and fracture

DIAGRAM 1.

(Steel as supplied.)



Curve 1. Primary test.		Curve 4. 2 weeks after 1.
,, 2. Shortly after 1.		,, 5. After heating to 200° C.
,, 3. $1\frac{3}{4}$ days ,, 1.		,, 6. ,, ,, ,,

would have occurred at probably a very slightly increased load. Recovery of elasticity was, however, effected as before, by heating the specimen to about 200° C., and allowing it to cool. It was known as the result of earlier experiments* that the yield-point of the material would be raised by this process through a second step of 11 tons, so that the specimen should not yield until a stress of 60 tons had been applied.

Curve No. 6 of Diagram 1 shows that the specimen bore the stress of 60 tons, but that with $60\frac{1}{2}$ tons per square inch, a yield-point and fracture occurred.

Diagram No. 2 shows that annealing altered in an interesting

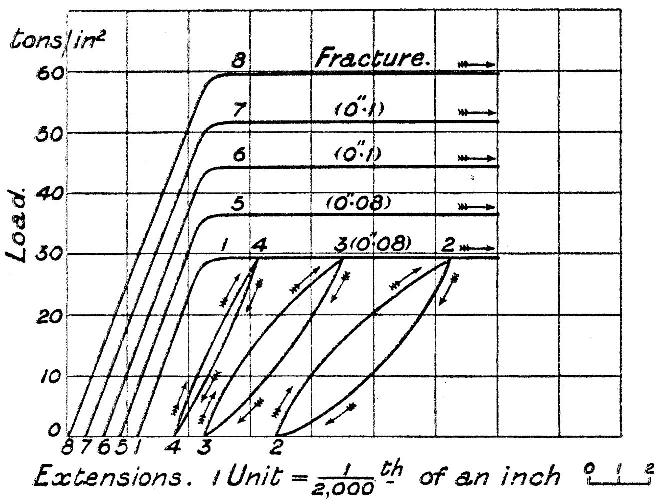
* *Ibid.*, p. 34.

manner the elastic properties of the steel whose virgin properties are illustrated by Diagram 1. The primary yield-point was considerably lowered by annealing, and the step by which the yield-point was raised in consequence of overstrain and recovery from overstrain was considerably reduced.

The material in the condition as supplied yielded (as is illustrated by Diagram 1) at 38 tons per square inch, and after the yield-point had been raised by *two* steps of 11 tons, fracture occurred at $60\frac{1}{2}$ tons per square inch. The same steel, after annealing at 750° C., is shown

DIAGRAM 2.

(Steel annealed at 750° C.)



Curve 1.	Primary test.	Curve 5.	After heating to 300° C.
,, 2.	Shortly after 1.	,, 6.	,, ,, ,,
,, 3.	$1\frac{3}{4}$ days ,, 1.	,, 7.	,, ,, ,,
,, 4.	2 weeks ,, 1.	,, 8.	,, ,, ,,

by Diagram 2 to have yielded at 29 tons per square inch, and finally to have fractured at $59\frac{1}{2}$ tons per square inch, after the yield-point had been raised *four* times by a step of about $7\frac{1}{2}$ tons per square inch. The $\frac{1}{2}$-inch steel rod when in the condition as supplied by the makers was thus shown to be in a state of hardness possessing certain distinctive properties.

It was found that the steel in the condition as supplied could be tempered or partially annealed by heating to various temperatures lower than the ordinary annealing temperature of about 750° C.

The following table illustrates this tempering from the condition as supplied, the material being a rod of steel very similar to that referred

to above. The "steps" tabulated in the last column are the amounts by which the yield-points were raised in consequence of overstrain and recovery from overstrain:—

Condition of the material.	Yield-point.	Extension at yield-point.	"Step."
As supplied	$36\frac{1}{2}$ tons/in.^{2}	0″·16 on 4 inches	11 tons/in.^{2}
Annealed at 600° C.	36 ,,	—	—
,, ,, 650° ,, ...	$33\frac{1}{2}$,,	0″·16 ,, ,,	$9\frac{1}{2}$,,
,, ,, 700° ,, ...	31 ,,	0″·15 ,, ,,	9 ,,
,, ,, 730° ,, ...	$28\frac{1}{2}$,,	0″·09 ,, ,,	8 ,,
,, ,, 780° ,, ...	24 ,,	0″·07 ,, ,,	7 ,,

In order to show the tempering of steel hardened by tensile overstrain, a specimen of annealed steel was overstrained in a manner analogous to that illustrated by Curves 1, 5, and 6 of Diagram 2. The material, after recovery from overstrain, had thus been brought into a condition of hardness, which enabled the specimen to be loaded to 50 tons per square inch without a yield-point being reached. The specimen was then subjected to a series of tests after being heated successively to various temperatures, the result being to show that 310° C. produced no softening of the material, 360° C. lowered the yield-point to 47 tons; 500°, 600°, and 700° C. lowered the yield-point to about 40, 35, and 30 tons per square inch respectively.

It was further shown that the same temperature brought the yield-point to approximately the same stress, no matter what might be the original hardness of the specimen under test; and that the harder the material was made by tensile overstrain—that is, the higher the yield-point was raised by permanent stretching—the lower was the temperature which could be shown to produce a slight tempering effect. Thus in the above instance had the material been made harder (by further overstraining) than was shown by the elastic range of from zero to 50 tons per square inch, then possibly the temperature of 310° C. would have produced a slight softening of the hardened material; a temperature of about 300° C. was, however, found to be the minimum temperature which had a tempering effect on the hardest condition of steel tested.

The tempering effects which have been ascribed above solely to temperature, were found to be influenced to some extent by time. Thus it was found that by baking a hardened specimen for several hours at any temperature a greater effect was produced than by simply raising the specimen for a few minutes to that temperature. The effect of time was, however, small compared with that produced by increase of temperature.

All the results which are described above for steel were also obtained with Lowmoor iron. The hardening by overstrain and the tempering of soft Lowmoor iron only differed in detail from the analogous hardening and tempering of steel.

The iron and steel employed in this research were also examined, when in various conditions of hardness, by means of the microscope, and micro-photographs are reproduced in the paper. The ordinary methods of relief polishing and of etching by dilute nitric acid were employed, and a new method of staining steel, by rubbing with ordinary moistened cocoa, was made use of and is described in the paper.

December 13, 1900.

Sir WILLIAM HUGGINS, K.C.B., D.C.L., President, in the Chair.

A List of the Presents received was laid on the table, and thanks ordered for them.

In pursuance of notice sent to the Fellows, an election was held to fill the vacancy upon the Council caused by the retirement of Sir John Wolfe Barry.

The statutes relating to the election of the Council, and the statute relating to the election of a Member of Council upon the occurrence of a vacancy, were read, and Professor Dewar and Mr. Godman having been, with the consent of the Society, nominated scrutators, the votes of the Fellows present were taken and Mr. Joseph Wilson Swan was declared duly elected.

The President made the following statement concerning the International Catalogue of Scientific Literature:—

"As stated in the Report of Council presented to the Society at the Anniversary Meeting, the President and Council offered to become the Publishers of the proposed International Catalogue, on behalf of the International Council, and to advance the capital sum needed to start the enterprise.

"I have now the pleasure of announcing that the International Council of the Catalogue, which met yesterday and to-day in the rooms of the Society, has accepted the offers of the Royal Society, and that this great undertaking, which has for several years engaged the earnest attention and demanded the continued labours of the Royal Society, as well as of other scientific bodies abroad and in this country, is now well on its way. The International Council has laid down all the necessary regulations, and prepared all the necessary instructions, for carrying